Lagrangian Floats for CBLAST

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LONG-TERM GOALS

I seek to understand the dynamics of the ocean boundary layer beneath hurricanes and the fluxes which drive it with the goal of improving ocean models at high wind speed.

OBJECTIVES

To measure turbulence properties and fluxes in the ocean boundary layer beneath hurricanes and relate them to hurricane properties and fluxes measured by others. To model the measured boundary layer properties using Large Eddy Simulation (LES) techniques with the twin goals of testing the models and investigating the boundary layer physics using the models.

APPROACH

Measurements. Neutrally buoyant Lagrangian floats will be air-deployed into hurricanes during the 2002, 2003 and 2004 hurricane seasons. The floats are a new type of neutrally buoyant float designed to be used in energetic turbulent flows such as those found in the top and bottom boundary layers of the ocean. A combination of accurate ballasting, compressibility matched to that of seawater and high drag is used to make these floats follow the motion of water parcels accurately (, D'Asaro 2003). Water velocity is inferred from the motion of the floats; high frequency fluctuations in velocity can be used to infer dissipation rate (Lien et. al 1998) and covariance of vertical velocity with scalars can be used to compute heat fluxes (Harcourt, et. al., 2002).

The CBLAST floats can operate in both a Lagrangian mode, as above, and as vertical profilers. They carry two CTD's, which provide highly accurate salinity and temperature, a highly accurate Doppler sonar for measuring shear, and ambient noise for measuring wind, rain and bubbles. These floats will be supplemented by additional NSF funded floats carrying gas sensors and designed to measure gas flux.

Modelling. The LES modeling work is being conducted by Ramsey Harcourt and Eric D'Asaro. Our starting point is a standard (Moeng, 1984) LES scheme using a subgrid closure with active kinetic energy as implemented by Harcourt et. al (2002) for the simulation of deep convection in the Labrador Sea. This model includes the ability to simulate the trajectories of both perfectly Lagrangian and realistically imperfect floats. This allows a direct comparison between the Larangian float observations and the Lagrangian model output.

Report Documentation Page

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1. REPORT DATE **30 SEP 2003**	2. REPORT TYPE	3. DATES COVERED **00-00-2003 to 00-00-2003**
4. TITLE AND SUBTITLE **Lagrangian Floats for CBLAST**		5a. CONTRACT NUMBER
		5b. GRANT NUMBER
		5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)		5d. PROJECT NUMBER
		5e. TASK NUMBER
		5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **APL/UW 1013 NE 40th Str,,Seattle,,WA, 98105**		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S)
		11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT
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15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**6**	

WORK COMPLETED

Hurricane Isodore. Four floats were deployed near Hurricane Isodore in late September, 2002 using a chartered aircraft. Three floats survived the air deployment. One was recovered by a Florida fisherman. One was recovered on a cruise of the *R.V. Seward Johnson* in November, 2002. The third could not be recovered because the ship could not safely operate near the Gulf Stream in November due to poor weather keeping ability and an inexperienced crew. A second recovery cruise was arranged for January 2003 on the *R.V. Knorr*. However, the ship hit a rock while leaving Woods Hole harbor and the cruise was terminated. Shortly thereafter, the float's satellite beacon died as its batteries expired.

Air Certification. Near heroic efforts by the 53rd Air Force Reserve squadron resulted in a set of air certification tests for the CBLAST floats in late July, 2003. The floats passed the tests. This was also the largest gathering of oceanographic air deployment technologists and resulted in the exchange of much useful information. As a result, we greatly strengthened the package by adding a wooden backbone and now use dissolving salt releases to free the float from the package.

Hurricane Fabian. Four floats were deployed by the 53rd Air Force Reserve squadron ahead of hurricane Fabian, a Category 3 storm with peak winds at the time of over 50 m/s. Last minute consultations between D'Asaro and Peter Black, CBLAST hurricane chief scientist, and the extraordinary flexibility and skill of the aircraft operators, resulted in fine tuning of the deployment array to match the hurricanes track. Floats were deployed on either side of the hurricane's eye.

Unfortunately, the skill in deployment was not matched by the results. The two CBLAST both survived air deployment, but suffered a software failure with resulting in premature termination of their mission. Both went through the highest winds of Fabian floating on the surface. One managed to transmit an *Iridium* message from the center of the storm, undoubtedly a first. The two NSF floats did not survive air deployment.

The two CBLAST floats were recovered on a rapid-response cruise of the *R.V. Cape Hatteras* a few weeks later. They have not yet been return to APL, but preliminary examination during the cruise indicates that one Iridium antenna was broken cleanly off the top of the float creating a potential leak path. The antenna design was changed at the last minute by the manufacturer and was much less sturdy than we had hoped. Clearly, we have some improvements to make before the 2004 season.

Modelling The modeling effort has concentrated on upgrading the model to operate in the upper ocean, using data from previous float deployments as a guide. We have added the vortex force of Craik and Liebovich (1976) and an *ad hoc* wave breaking parameterization in which a fraction of the wave momentum enters in periodic wave breaking events, while the remainder is applied uniformly over the water surface. Model runs have been made based on float data from the wintertime North Pacific (D'Asaro, 2001).

RESULTS

Hurricane Isidore. Data from the two floats retreived from Hurricane Isidore show ocean boundary layer conditions very simiar to those found at similar wind speeds in other locations. As shown in Fig. 1a, the floats oscillate vertically within the mixed layer tracking the vertical motion of water parcels at

typical speeds of 3 cm/s. Cooling from the surface and below results in a net cooling of the mixed layer (Fig. 1b); mixing of salty water from below results in an increase of mixed layer salinity (Fig. 1c). More quantitative analysis yields:

- Vertical kinetic energy profiles compute by two independent methods agree well. This implies that the floats are sampling the boundary layer without significant biase due to buoyancy or other problems.

- Vertical kinetic energy is proportional to wind stress as found by D'Asaro (2001) and with a similar constant of proportionality. This strengthens the case that despite complications such a Langmuir circulations, details of the surface wave field do not affect the overall boundary layer energetics.

- The three terms in the horizontally averaged heat equation can be computed (Fig. 1d.) and sum to close the heat budget within large error bars.

- Heat transfer is primarily vertical; horizontal processes play a small role. This is quite different from what was found in Hurricane Dennis (D'Asaro, 2003a) where horizontal effects were large.

- The mixed layer cooling due to surface heat flux and entrainment heat flux are roughly equal at about 300 W m^2. The resulting buoyancy fluxes therfore nearly cancel and play a small role in the boundary layer energetics.
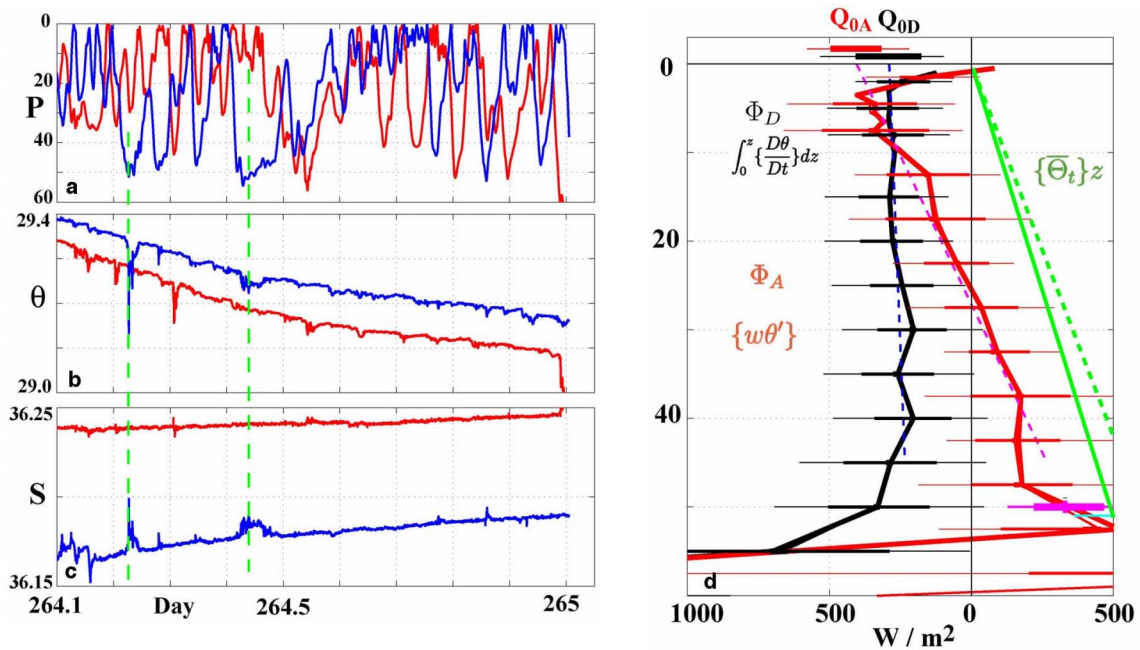

Figure 1. a) Depth-time trajectories of two floats deployed in Hurricane Isidore. b) Time history of temperature at each float. c) Time history of salinity at each float. d).Profiles of the the three terms in the horizontally averaged vertically integrated heat flux equation for the mixed layer in Hurricane Isidore as measured by Lagrangian floats. The terms are: "Mixed layer average heat content change times depth" (green) = "Vertical advective heat flux"(red) + "Integrated Lagrangian heating". Extrapolating the second and third terms to the surface yields independent surface heat fluxes of 403 83 W m^2 and 277 117 W m^2 respectively; they agree within the error bars indicating that the calculations are consistent.

Modelling. Fig. 2 shows typical results from the LES modeling. Historical float data, including that taken in Hurricane Isidore, clearly shows a very strong correlation between wind stress and vertical kinetic energy as shown in Fig. 2a. The level is about twice that for a shear-driven boundary layer. The LES model, with realistic forcing (Fig. 2b), yields a similarly high correlation, but with too little kinetic energy. Sensitivity studies reveal that the model kinetic energy and its average dissipation rate are sensitive to the magnitude of the Stokes drift. If the Stokes drift is not included, there seems to be no way to get the kinetic energy large enough to match the observations. However, the measured wave spectra, and computed Stokes drifts, still result in a modeled vertical kinetic energy smaller than observed. We suspect that this is an error in the wave spectra measurement and are working on correcting the spectra for instrumental effects.

The wave breaking parameterization greatly increases the near-surface energy dissipation rate, but has little effect on the overall level of kinetic energy in the boundary layer. This is partially because momentum added to the boundary layer by breaking is subtracted from the uniform momentum input. The boundary layer interior does not appear sensitive to the exact way in which momentum is added.
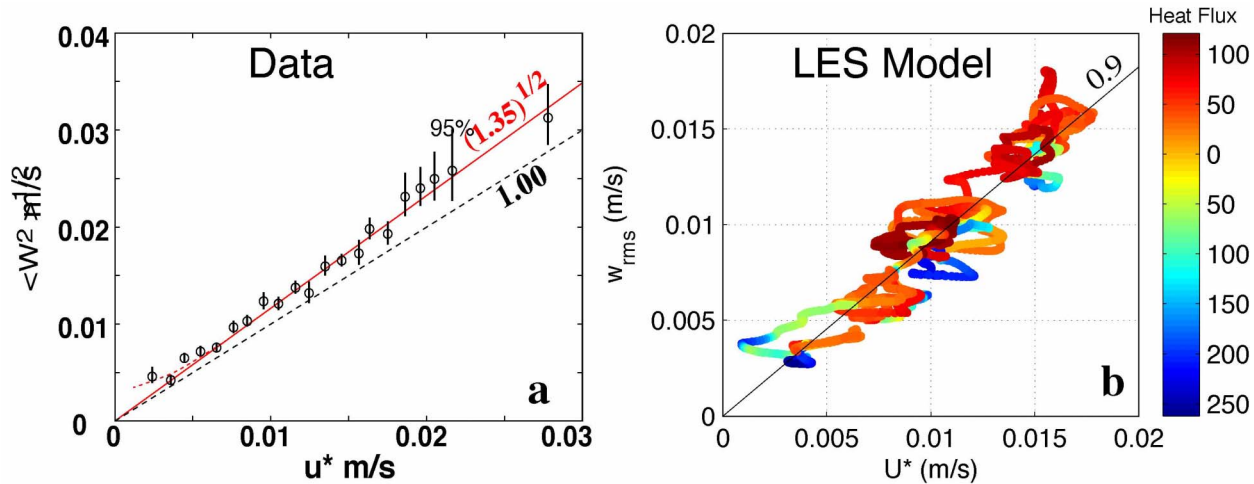

Figure 2. a) Strong correlation between rms vertical velocity from Lagrangian float data and u*, the friction velocity, computed from bulk formulae. Data is from the wintertime North Pacific (D'Asaro, 2001). b) LES model using Craig-Liebovich forcing with realistic atmospheric forcing yields similar good correlation. Heat flux, as indicated by the line color, does not affect correlation.

IMPACT/APPLICATIONS

None (Yet)

TRANSITIONS

None

RELATED PROJECTS

These floats are nearly identical to those used in studies of circulation and mixing off Oregon.

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